PATENT SPECIFICATION

DRAWINGS ATTACHED

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887,574

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COMPLETE SPECIFICATION

Improvements in or relating to Electric Wave Filters

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63, Aldwych, London, W.C.2, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electric wave filters, and concerns a branching waveguide filter arrangement for combining or separating communication signals occupying different frequency bands.

Such filters are commonly used in microwave communication systems, and may be applied for example, to combine or separate the signals which are transmitted, by, and received on, a common antenna system.

A filter of this type has already been proposed comprising a main hollow waveguide of rectangular or square cross-section capable of transmitting signals occupying both of two separated frequency bands, and arranged parallel thereto a secondary rectangular hollow waveguide capable of transmitting signals occupying the upper frequency band. The two waveguides are coupled by a number of short branching waveguides arranged normally to the main and secondary waveguides, and communicating therewith through appropriate slots or apertures. The branching waveguides are dimensioned so that they will transmit signals in the upper band but not signals in the lower band. The branching waveguides are spaced apart parallel to the axes of the main and secondary guides by equal intervals. Then if signals occupying both bands are transmitted into the main guide those occupying the upper frequency band are diverted to the secondary guide, while the others continue in the main guide.

This arrangement is subject to the production of a number of unwanted modes of propagation, and the object of the present invention is to modify the arrangement so that at least some of the unwanted modes are effectively eliminated or reduced. This object is achieved according to the invention by using for the secondary waveguide a waveguide of the type known as a "ridge guide," instead of an ordinary rectangular waveguide. The term ridge waveguides as used in this specification and claims refers to ridge waveguides of the type described in "Properties of ridge Wave Guide," by S. B. Cohn in Proc.I.R.E. August 1947. These waveguides differ from ordinary waveguides in that one or both wide walls of the guides have a ridge running along the length of the guides. This is equivalent to uniformly distributed capacity loading and has the effect that for a given cut-off frequency of the dominant mode ridge waveguides have a higher cut-off frequency for the higher order modes than ordinary waveguides. Ridge waveguides have therefore a wider frequency band which will propagate only the dominant mode. Certain of the unwanted modes cannot be supported in a ridge waveguide and are accordingly eliminated.

The invention accordingly provides an electric wave filter for separating or combining an electric wave having a frequency lying in a lower frequency band having lower and upper frequency limits F_1 and F_2, and an electric wave having a frequency lying in an upper frequency band having lower and upper frequency limits F_3 and F_4, where F_3 is greater than F_2, comprising a main hollow waveguide adapted to transmit waves having frequencies lying in both frequency bands, a secondary waveguide consisting of a ridge guide arranged with its axis substantially parallel to the axis of the main waveguide, a plurality of branching guides each forming a coupling between the main waveguide and the secondary waveguide, the said branching guides consisting of rectangular waveguides having their lower cut-off frequency lying between F_2 and F_3 and being arranged with their central H-planes perpendicular to the

axes of the main and secondary waveguides, and spaced apart at substantially equal intervals, and means for terminating one end of the secondary waveguide with a reflectionless termination.

Another advantage of using the ridge guide is that an upper frequency band with a larger bandwidth can be handled than when an ordinary rectangular waveguide is used.

The invention will be described with reference to the accompanying drawings, in which:—

Fig. 1 shows a front elevation of a waveguide filter according to the invention;

Fig. 2 shows a top view of the filter as seen in the direction of the arrow A in Fig. 1;

Fig. 3 shows a section taken along the dotted line B—B of Fig. 1;

Fig. 4 shows part of a side elevation as seen looking towards the left-hand side of Fig. 1;

Fig. 5 shows a section at C—C of Fig. 1;

Fig. 6 shows a top view similar to Fig. 2 to illustrate an extension of the filter of Figs. 1 to 5; and

Fig. 7 shows a modification of the section of Fig. 3 to illustrate a minor modification of the invention.

It should be understood that the figures are not drawn to scale, and are not intended to indicate relative values of the various dimensions.

In order to make the invention clear, it will be assumed that the filter according to the invention is intended to combine signals occupying a lower frequency band bounded by frequencies F_1 and F_2 with signals occupying an upper frequency band bounded by frequencies F_3 and F_4 (or alternatively to separate signals occupying these bands). It is assumed that F_1 to F_4 are in ascending order of magnitude. As an example of the application of the filter according to the invention, the frequencies F_1 to F_4 may have the following values:—

F_1 3,600 Megacycles per second (Mc/s)
F_2 6,500 „ „ „
F_3 10,700 „ „ „
F_4 11,700 „ „ „

The lower band from 3,600 to 6,500 Mc/s may itself comprise two separate frequency bands.

Referring to Figs. 1 to 5, one embodiment of a filter according to the invention comprises a main hollow waveguide 1 of square cross-section having a cut-off frequency below F_1, and two similar secondary waveguides 2 and 3 arranged parallel to the waveguide 1, and on opposite sides thereof. According to the invention, the secondary waveguides are ridge guides, the cross-section of which can be seen in Fig. 3. As is well known, a ridge guide is a waveguide having a rectangular cross-section which is partly filled up by a rectangular longitudinal ridge attached to one of the wider walls of the guide. The cross-section of the ridge can be seen at 4 in Fig. 3. The cut-off frequency of the ridge guides should preferably be the same as that of the main guide 1.

In this specification the term "rectangular waveguide" will be used to mean a hollow waveguide of square or rectangular cross-section not occupied by any ridge, while if a ridge is present the waveguide will be called a "ridge guide."

The main waveguide 1 is coupled to the secondary waveguides by means of two corresponding series of small branching guides 5 of rectangular cross-section. Six branching guides are shown in each series, but other numbers could be used, according to circumstances. In some cases, for example, the number of branching guides in each group may be from 12 to 30. The branching guides communicate with the main and secondary guides through rectangular slots of the same dimensions as the cross-section of the branching guides.

The branching guides 5 should have a cross-section such that the cut-off frequency lies between F_2 and F_3, so that they will transmit waves of frequencies lying in the upper band F_3 to F_4, but not those of frequencies lying in the lower band F_1 to F_2. Furthermore, the branching guides 5 in each series should preferably be spaced so that the distance between the central planes normal to the electric vector (called the "H-planes") of adjacent branching guides is equal to about a quarter of the wavelength in the guide at the mid-band frequency of the upper band, but this is not critical. The spacing could be anything from one-eighth to three-eighths of a wavelength.

The length of the branching guides should normally be about a quarter of the guide wavelength at the upper mid-band frequency, but again this could be between one eighth and three-eighths of the guide wavelength.

Furthermore, rather greater lengths for the branching guides may be necessary in some cases to obtain sufficient suppression of the lower band. Thus another favourable length would be three-quarters of a wavelength, with limits between five-eighths and seven-eighths of a wavelength.

The lower ends of the secondary guides 2 and 3 are connected by rectangular waveguides 6 and 7, called extension guides, to a T-joint 8 (Fig. 2) of the E-plane type, and thence to a common output rectangular waveguide 9. There are conventional chamfered E-bends at 10 and 11 in the extension guides 6 and 7, and also chamfered H-bends, of which one is shown at 12 in Fig. 4.

The ridge guides 2 and 3 have to be appropriately coupled to the extension guides 6 and 7. Part of the front-wall of the ridge guide 2 has been shown removed in Fig. 1, in order to show how this may be done. The height of the ridge 4 (which is shown shaded)

is reduced at the lower end in a number of rectangular steps indicated at 13 until it is entirely removed. Actually three steps are shown for illustration, but it will be understood that a larger number of steps may be necessary to provide a satisfactory transition.

The upper ends of the secondary waveguides 2 and 3 are closed and provided with suitable non-reflecting terminations (not shown). The common output guide 9 and the upper and lower ends of the main waveguide 1 will be coupled by conventional means to the associated waveguide equipment (not shown).

If now waves occupying the upper and lower frequency bands and operating in the TE_{10} mode are transmitted into the upper end of the main waveguide 1 with the electric vector perpendicular to the dotted line 14 in Fig. 2, the waves in the upper band will be transmitted through the branching guides 5 to the two secondary waveguides 2 and 3 and will emerge combined from the output guide 9. However, the waves in the lower band will not be transmitted by the branching guides 5, and will emerge from the lower end of the main guide 1.

It should be mentioned here that the number of branching guides and their dimensions should preferably be chosen so that substantially complete transfer of power is obtained from the main guide to the secondary guides at all frequencies in the upper frequency band.

It is evident that the filter arrangement will operate in the opposite direction. Thus if waves occupying the lower band are supplied to the lower end of the main waveguide 1 and waves occupying the upper band are supplied to the output guide 9, both series of waves will be combined and will emerge together at the upper end of the main waveguide 1.

It may be pointed out that a further advantage of using ridge guides for the secondary waveguides is that there is produced a much closer coupling between the secondary guide and the branching guides, than if the secondary waveguides were rectangular waveguides. To achieve the same coupling, in the latter case, it would be necessary to use at least double the number of branching guides in both series; or alternatively, with the same number of branching guides, each should have at least the dimension parallel to the E vector doubled.

It has already been mentioned that a number of the unwanted modes which tend to be generated in the apparatus cannot be supported in the ridge guides and are accordingly substantially eliminated from the upper band.

Referring to Fig. 2, the plane through the dotted line 14 parallel to the axis of the main waveguide 1 is a plane of symmetry, and if a conducting septum were introduced in this plane, the propagation of the waves in the main waveguide 1 would be substantially unaltered. It follows that if the square main waveguide were divided in this way into two rectangular waveguides, the right hand waveguide (for example) could be removed without affecting the transmission in the left hand waveguide. Thus the right hand secondary waveguide 3 together with all the branching guides on the right hand side and also the extension guide 7 and the T-joint 8 could be removed, and the simplest form of the invention would then result.

In this form, the main waveguide 1 comprises a rectangular waveguide coupled by a series of branching guides to a single secondary ridge guide 2 arranged on one side of the main waveguide. In this case the secondary waveguide could continue as far as desired as a ridge guide, and could at any point be transformed into a rectangular waveguide, as may be convenient.

Fig. 6 shows a top view of an extension of the filter which has been described with reference to Figs. 1 to 5. Fig. 6 is on similar lines to Fig. 2, but on a smaller scale. In addition to the elements shown in Fig. 2, Fig. 6 shows two further secondary ridge guides 15, 16 coupled respectively to the two remaining sides of the main guide 1 by corresponding series of branching guides 17 and 18, and to an output guide 19 by extension guides 20 and 21, and a T-joint 22. The elements 15 to 22 are similar to the previously described elements illustrated in Figs. 1, 3, 4 and 5, except that the secondary guides 15 and 16 are somewhat longer than 2 to 3 to enable the extension guide 21 to pass below the extension guide 7, as indicated in Fig. 6. If now the square main waveguide 1 is supplied with two groups of waves polarised at right angles, then the waves of the upper band having the electric vector normal to the dotted line 14 will emerge from the output guide 9, while those polarised with the electric vector parallel to the dotted line 14 will emerge from the output guide 19. It should be noted that the two groups of waves do not necessarily have to occupy the same frequency bands; the branching guides 17 and 18 can be differently spaced and proportioned from the branching guides 5.

It has so far been assumed that all the branching guides have the same cross-section. However, a reduction in the number of branching guides can be obtained if their heights (that is, the smaller dimensions of the cross-sections) are varied so that the heights of the branching guides at the ends of the group are less than those in the centre of the group. This has the effect of grading or tapering the impedances presented by the branching guides.

As examples of the design of the filter illustrated in Figs. 1 to 5, the following

dimensions are given for the particular frequency bands already mentioned, namely, lower band 3,600 to 6,500 Mc/s; upper band 10,700 to 11,700 Mc/s:—

A. With branching guides all of the same cross-section:—

Number of branching guides in each group 30

	Cross-Section Internal Dimensions: inches
Main waveguide 1	2.00 × 2.00
Ridge guides 2 and 3	0.90 × 0.40
Ridge	0.340 × 0.187
Branching guides	0.600 × 0.062
Branching guides: length	0.600

B. With branching guides of different cross-sections:—

Number of branching guides in each group 12

Internal cross-section width of all branching guides: 0.600 inch

The branching guides in each group being numbered in order from 1 to 12, the cross-section heights were as follows:—

Nos. 1 and 12	0.05 inch
Nos. 2 and 11	0.10 inch
Nos. 3 to 10	0.20 inch.

The dimensions of the main and ridge guides were as for example A.

Although it has been assumed that the main waveguide 1 is of square or rectangular cross-section, it could alternatively be a circular guide. This is illustrated by the section shown in Fig. 7, which is similar to Fig. 3. In this case, it is assumed, for example, that there is only one secondary waveguide which is the same as the ridge guide 2 and is coupled to the circular main guide 1 by a series of branching guides, one of which is shown in sections at 5 in Fig. 7. Apart from the fact that the main waveguide is circular, the assembly is generally as shown in Fig. 1 with the right hand ridge guide 3 and the associated elements omitted.

WHAT WE CLAIM IS:—

1. An electric wave filter for separating or combining an electric wave having a frequency lying in a lower frequency band having lower and upper frequency limits F_1 and F_2, and an electric wave having a frequency lying in an upper frequency band having lower and upper frequency limits F_3 and F_4, where F_3 is greater than F_2, comprising a main hollow waveguide adapted to transmit waves having frequencies lying in both frequency bands, a secondary waveguide consisting of a ridge guide arranged with its axis substantially parallel to the axis of the main waveguide, a plurality of branching guides each forming a coupling between the main waveguide and the secondary waveguide, the said branching guides consisting of rectangular waveguides having their lower cut-off frequency lying between F_2 and F_3 and being arranged with their central H-planes perpendicular to the axes of the main and secondary waveguides and spaced apart at substantially equal intervals, and means for terminating one end of the secondary waveguide with a reflectionless termination.

2. A filter according to claim 1 in which the secondary waveguide has the same cut-off frequency as the main waveguide.

3. A filter according to claim 1 or 2, in which the other end of the secondary waveguide is coupled to an extension guide comprising a rectangular waveguide, by a transition section of the ridge guide in which the height of the ridge is reduced substantially to zero in a series of discrete steps.

4. A filter according to claim 1, 2 or 3, in which the main waveguide is of circular cross-section.

5. A filter according to claim 3 in which the main waveguide is of square cross-section, and in which the secondary waveguide is coupled by the branching guides to one wall of the main waveguide, and in which a second secondary waveguide, similar to the first-mentioned secondary waveguide and comprising a ridge guide, is coupled in like manner to the opposite wall of the main waveguide by a secondary plurality of branching guides, the second secondary waveguide being also coupled to a second extension guide of rectangular form by a transition section in like manner to the first-mentioned secondary waveguide, and in which the two extension guides are coupled to an output rectangular waveguide by an E-plane T-joint.

6. An electric wave filter comprising a main hollow waveguide of square cross-section and four secondary waveguides arranged with their axes substantially parallel to the axis of

the main waveguide, and each consisting of a ridge guide, each secondary waveguide being coupled to a corresponding one of the four walls of the main waveguide by a corresponding group comprising a plurality of branching guides each of which consists of a rectangular waveguide and is arranged so that its H-plane is normal to the axis of the main waveguide, the central H-planes of the branching guides in each group being equidistant, in which the main waveguide is dimensioned to have a first predetermined lower cut-off frequency, and in which the branching guides are each dimensioned to have a lower cut-off frequency higher than the first predetermined cut-off frequency, the filter further comprising first and second extension guides consisting of rectangular waveguides each coupled by a transition section to one end of a corresponding one of two of the secondary waveguides which are respectively coupled to one pair of opposite walls of the main waveguide, a first E-plane T-joint connecting the first and second extension guides to a first rectangular output guide, and two non-reflecting terminations connected respectively to the other ends of the last-mentioned two secondary waveguides.

7. An electric wave filter according to claim 6, further comprising third and fourth extension guides consisting of rectangular waveguides each coupled by a transition section to one end of a corresponding one of the remaining two secondary waveguides, a second E-plane T-joint connecting the third and fourth extension guides to a second rectangular output guide, and two further non-reflecting terminations connected respectively to the other ends of the last-mentioned two secondary waveguides.

8. A filter according to claim 7, in which the lower cut-off frequencies of all the secondary waveguides are the same as that of the main waveguide, and in which the distance between adjacent H-planes of the branching guides in each group is equal to a quarter wavelength at a frequency above the lower cut-off frequency of the secondary waveguides.

9. An electric wave filter substantially as described and as illustrated in Figs. 1 to 5 of the accompanying drawings.

10. A modification of the filter according to claim 9, substantially as described with reference to Fig. 6 or to Fig. 7 of the accompanying drawings.

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Chartered Patent Agent for the Applicants.

Reference has been directed in pursuance of Section 9, subsection (1) of the Patents Act, 1949 to patent No. 820,632.

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FIG. 1.

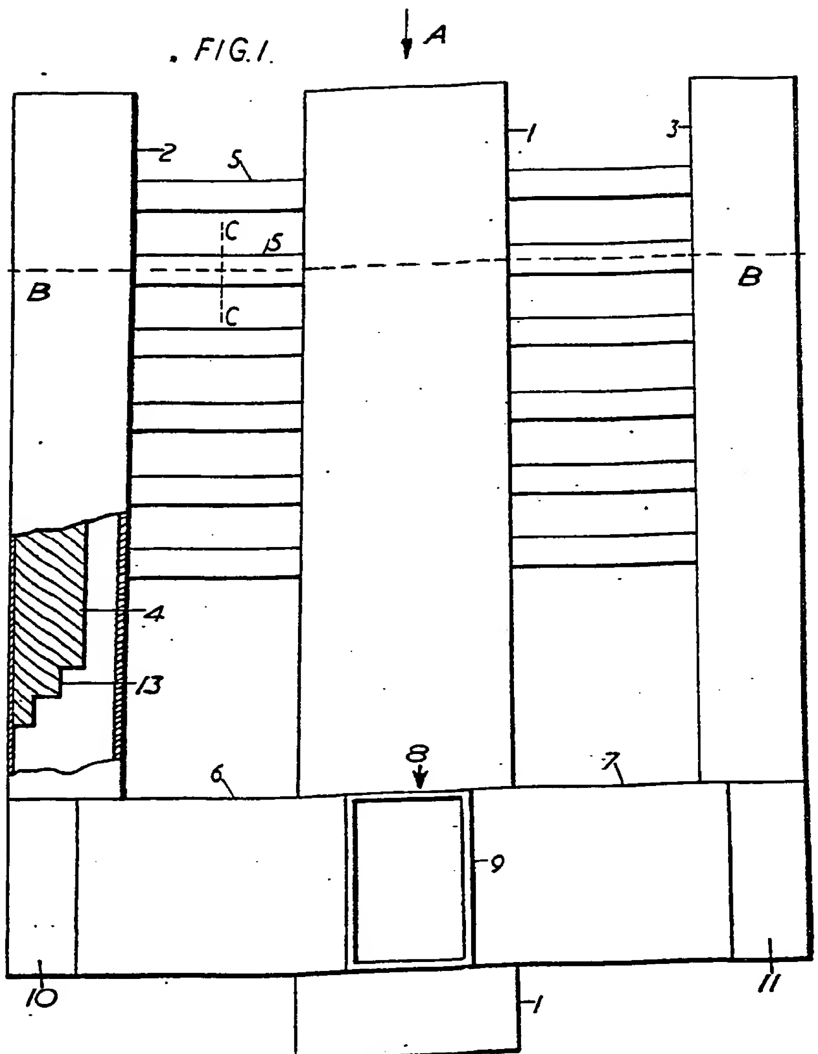
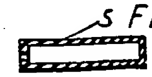


FIG. 5.



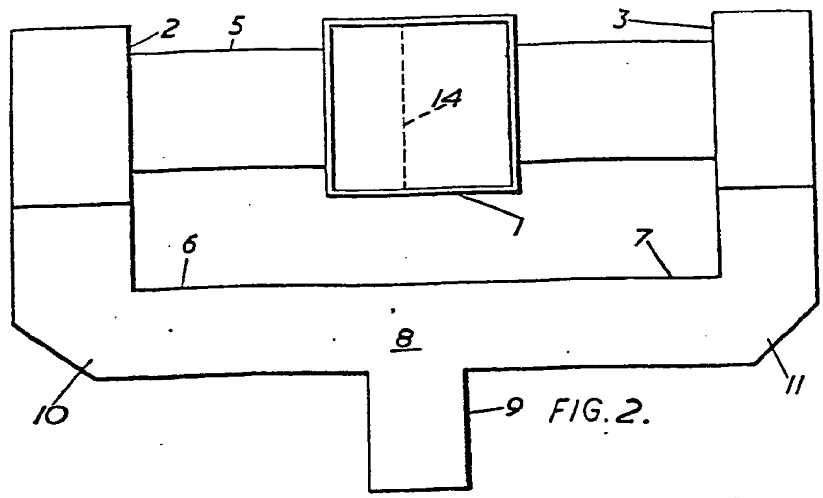


FIG. 2.

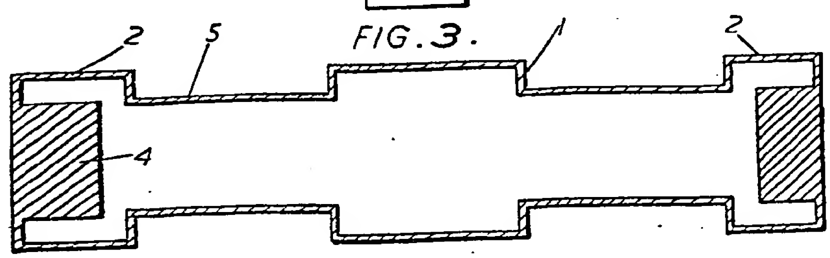


FIG. 3.

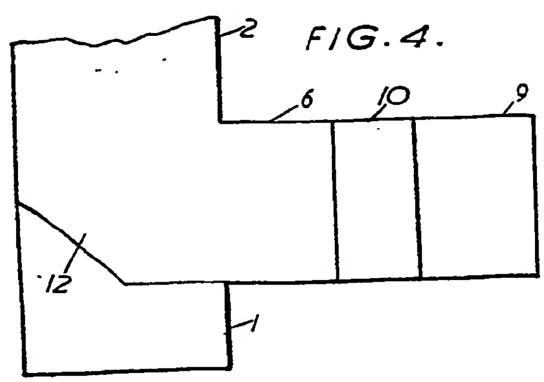


FIG. 4.

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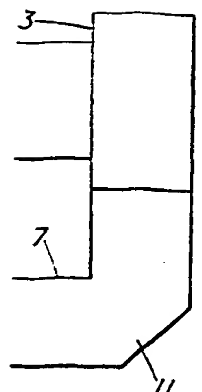
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 2 & 3



2.

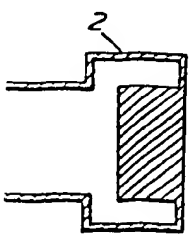


FIG.6.

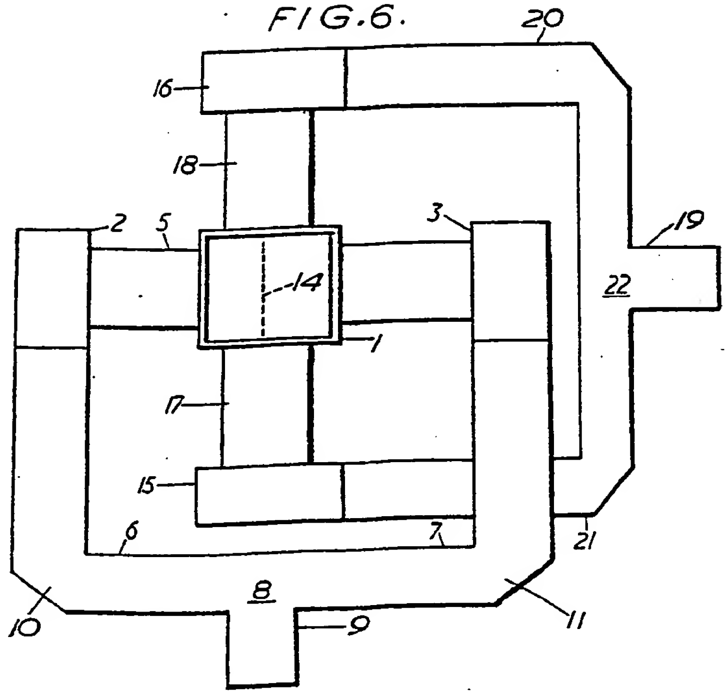
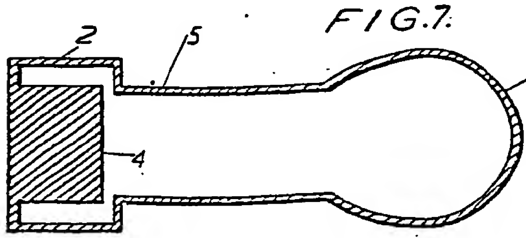


FIG.7.



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Sheets 2 & 3

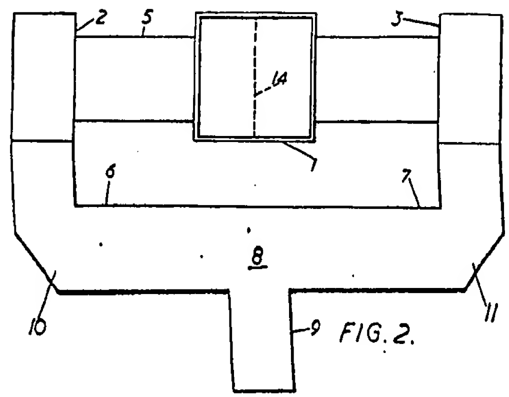

FIG. 2.

FIG. 3.

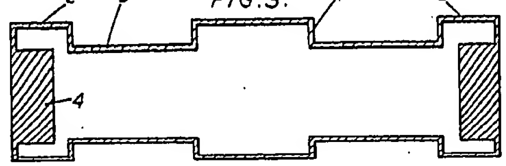

FIG. 4.

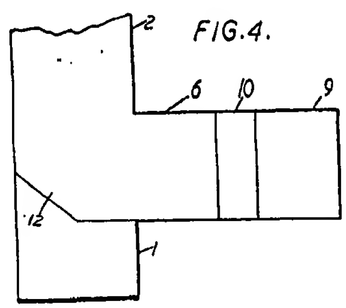

FIG. 6.

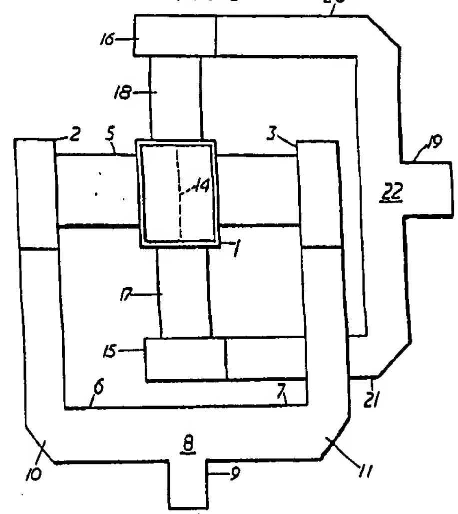

FIG. 7.